

Nyastra: A Digital Tool for Learning and Preserving Balinese Script

I Wayan Mulyawan (corresponding author)

English Department, Faculty of Humanities

Udayana University, Bali - Indonesia

I Wayan Suardiana

Balinese Department, Faculty of Humanities

Udayana University, Bali - Indonesia

I Ketut Ngurah Sulibra

Balinese Department, Faculty of Humanities

Udayana University, Bali - Indonesia

I Gede Santi Astawa

Computer Department, Faculty of Mathematics and Natural Science

Udayana University, Bali - Indonesia

Received: May 24, 2026 Accepted: June 28, 2026 Published: July 12, 2026

doi:10.5296/ijld.v16i2.23780

URL: <https://doi.org/10.5296/ijld.v16i2.23780>

Abstract

The declining interest among Bali's youth in learning Balinese script, juxtaposed with a local mandate for its public use (Governor Regulation No. 80 of 2018), presents a critical challenge for cultural preservation. This study aimed to develop and evaluate the effectiveness of the Nyastra web-based application (<https://nyastra.co.id/>) as a digital tool to support the learning and accurate transliteration of Balinese script. Employing a mixed-methods approach, the research combined a quasi-experimental, one-group pretest-posttest design with qualitative case-study observations at State Junior High School (SMP N) 1 Kuta, Bali, Indonesia.

Grounded in theories of digital learning and Computer-Assisted Language Learning (CALL), the intervention involved 22 8th-grade students using the application over a structured period. Quantitative analysis revealed a substantial improvement in transliteration accuracy, with the class average score increasing from 42.35% to 74.12%. Qualitative data indicated high user satisfaction (rated 10/10), increased classroom engagement, and ancillary benefits in English pronunciation. However, findings also identified technical limitations in handling complex script rules, underscoring the application's role as a complementary pedagogical tool rather than a standalone solution. The study concludes that the Nyastra application is an effective digital medium that can bridge policy goals with educational practice, offering a viable model for technology-enhanced cultural preservation in the digital era.

Keywords: Nyastra, Balinese transliteration, digital literacy, local script, Bali

1. Introduction

In the contemporary era of digital advancements, the education landscape has undergone a significant transformation, reshaping traditional teaching and learning methods. The integration of technology in educational practices exposes students to innovative tools and resources that enhance their learning experiences (Bower, 2017; Qolamani & Mohammed, 2023). One such digital learning medium that has gained prominence is Nyastra, a Balinese transliteration platform designed to facilitate students' learning of the Balinese script. This study explores the impact of Nyastra, a digital transliteration tool, on Balinese script education through a detailed case study conducted at State Junior High School (SMP N) 1 Kuta, Bali, Indonesia.

Despite growing interest in digital learning tools for cultural and linguistic education, a gap remains in the literature on the specific impact of these tools on the learning outcomes of students studying indigenous scripts, such as Balinese. While studies have highlighted the benefits of technology in language learning more broadly, there is a need for research that delves into the unique challenges and opportunities presented by digital platforms in preserving and teaching traditional scripts. This also underscores the need for tailored approaches that resonate with students' cultural backgrounds (Eutsler & Perez, 2022). However, applying these principles to teaching Balinese script on platforms like Nyastra remains underexplored. By addressing this gap, this study contributes to a deeper understanding of the potential of digital tools in promoting cultural heritage and language preservation. On the other hand, challenges arise in integrating digital tools into indigenous language education and in adopting culturally sensitive approaches. This study emphasises the importance of considering cultural nuances and historical contexts when developing a digital transliteration app for Indigenous languages, including the application of standard rules in writing Balinese script for foreign words. This factor is crucial in teaching Balinese script, as it is significantly different from the Latin script.

Additionally, safeguarding intangible cultural heritage, including traditional scripts and languages, through digital technologies and copyright, is crucial (Wagner & De Clippele, 2023). The report calls for increased research and investment in digital tools to support the preservation and transmission of Indigenous knowledge systems, aligning with the objectives of utilising platforms such as Nyastra for Balinese script education. The Balinese script, a

traditional writing system in Bali, Indonesia, symbolises the Balinese people's cultural identity and historical legacy. Furthermore, Balinese script serves as a means of communication and reflects the rich cultural heritage and artistic traditions of the Balinese community (Abdi Putra & Paramarta, 2023). Therefore, understanding and preserving this script is essential for maintaining the unique identity and heritage of the Balinese people.

Incorporating the Balinese script into the educational curriculum plays a crucial role in preserving Bali's cultural heritage and promoting linguistic diversity among students. Exposure to indigenous scripts, such as Balinese, fosters a sense of pride and connection to one's cultural roots (Asroni et al., 2025). Yet the proposed apps do not accommodate the transliteration of foreign languages into Balinese script as used in Nyastra. By learning the Balinese script, students gain linguistic skills and a deeper appreciation of the cultural traditions and values embedded in it. Moreover, studying traditional scripts, such as Balinese, can enhance students' cognitive development and critical thinking skills (Sudarma et al., 2024). The intricate nature of the Balinese script requires attention to detail, spatial awareness, and memory retention, which can contribute to cognitive growth and linguistic proficiency. By incorporating Balinese script education into the curriculum, teachers can provide students with a holistic learning experience that nurtures cultural awareness and cognitive abilities.

Digital platforms like Nyastra represent a paradigm shift in how students engage with cultural and linguistic heritage, particularly the Balinese script. By incorporating technology into the teaching of traditional scripts, teachers can bridge the gap between heritage preservation and modern educational practices, offering students a dynamic and interactive learning environment (Meighan, 2021). Through a comprehensive analysis of the case study at SMP N 1 Kuta, this study aims to assess the effectiveness of Nyastra in improving transliteration accuracy in a classroom setting and to examine its role as a tool for cultural preservation.

2. Methodology

2.1 Research Design

This study employed a quantitative research approach, focusing on the collection and analysis of numerical data to test hypotheses and establish relationships between variables (Abbas, 2023; Creswell, 2014). Specifically, the research utilised a one-group pre-test-post-test design. This quasi-experimental method is widely used in educational settings to measure the impact of an intervention by comparing a single group's performance before and after a treatment (Shadish et al., 2002). The design was implemented in a practical case study at SMP N 1 Kuta to evaluate the effectiveness of the Nyastra application in improving students' ability to transliterate from Latin into Balinese script.

2.2 Research Procedures

The research was conducted at SMP N 1 Kuta, a junior high school in Bali. The procedures were systematically sequenced as follows:

1. **Pre-Test Administration:** Students were given a pre-test assessment designed to measure their baseline transliteration skills. They manually transliterated sentences

from English, Indonesian, and Balinese (in Latin script) into correct Balinese script without using the Nyastra application or any digital aids.

2. **Intervention Period:** Following the pre-test, students used the Nyastra application as the core learning tool over a designated instructional period, facilitated by their Balinese teacher.
3. **Post-Test Administration:** After the intervention, students completed a post-test. They were given a similar set of sentences and used the Nyastra application to perform the transliteration. The post-test sentences were comparable in difficulty and length to ensure test reliability (Bobbitt, 2021).

2.3 Participants and Intervention Implementation Process

The application was implemented and tested at SMP N 1 Kuta, involving a convenience sample of 22 8th-grade students. This testing phase served as the empirical intervention for this study, integrating the app into the existing Balinese language curriculum under the guidance of the subject teacher.

This grade level was selected because students are typically at a foundational stage in their Balinese language and script education, making them an ideal group for assessing the application's learning-support capabilities. The intervention centred on the structured use of the Nyastra platform. The implementation process involved training students in the app's functionality and integrating it into their regular lessons, under the guidance of the Balinese teacher. This aligns with digital learning principles, leveraging technology to create interactive, personalised experiences that promote engagement and knowledge retention (Naveed et al., 2023; Oskarita & Arasy, 2024), while allowing students to learn at their own pace (Rafiq et al., 2024).

2.4 Data Analysis Methods

The primary data collection instruments were the pre-test and post-test assessments, designed to ensure content validity by measuring transliteration skills across different languages. The core data for analysis were the numerical scores from those tests. The data were analysed using quantitative methods. The scores from both tests were compared to determine if there was a statistically significant improvement in students' transliteration accuracy after using the Nyastra application. This analysis focused on identifying a positive correlation between app use and improved performance, providing empirical evidence of the app's effectiveness. This quantitative analysis was framed within a case study approach, enabling a comprehensive evaluation of the digital tool's impact on the learning environment.

3. Results

This section presents the study's integrated findings, synthesising quantitative performance data with qualitative observations and user feedback. The results are organised to address the core research objectives: evaluating the effectiveness of the Nyastra application in improving transliteration accuracy, assessing its pedagogical benefits and challenges in a classroom setting, and examining its role as a tool for cultural preservation.

3.1 Implementation of the Nyastra Application

The primary outcome of this research is the successful development of the Nyastra application, a web-based transliteration tool accessible at <https://nyastra.co.id>. This product represents a convergence of socio-cultural studies and computer application development, creating an innovative platform to support the preservation of Balinese script. The development was driven by a recognised cultural imperative: Balinese script, a precious historical heritage, faces declining interest among the younger generation amidst technological advancement (Erawati et al., 2023; Mulyawan, 2021). This decline occurs paradoxically alongside the Bali Provincial Government's Governor Regulation No. 80 of 2018, which mandates the use of Balinese script in public spaces—a policy challenging to implement due to difficulties in achieving accurate and standardised transliteration.

The application was designed with a dual user base in mind: the general public requiring transliteration for official signs and public displays, and educational actors (teachers and students) engaged in formal Balinese language learning. Its development followed a structured process involving needs analysis, compilation of a transliteration rule database, application programming, and iterative testing. Key technical features implemented include:

1. **Text-Based Input and Output:** The fully functional core allows users to input Latin text for conversion to Balinese script and vice versa.
2. **Bi-Directional Transliteration:** The application supports conversion from Latin to Balinese script and from Balinese script back to Latin, essential for learning and verification.
3. **Adherence to Standard Orthographic Rules:** The algorithm incorporates standard Balinese writing conventions, including specific rules for borrowed vocabulary.

3.2 Quantitative Impact on Transliteration Accuracy

To objectively measure the application's effectiveness, a one-group pre-test-post-test design was employed. A cohort of 11 student pairs completed assessments before and after using the Nyastra application during the intervention period. The pre-test established a baseline by requiring students to manually transliterate sentences from English, Indonesian, and Balinese (in Latin script) into correct Balinese script without digital aids. The post-test, featuring sentences of equivalent difficulty, allowed students to use the Nyastra application to complete the transliteration tasks.

Table 1. Pre-Test vs. Post-Test Result

Student	Pre-test Accuracy (%)	Post-test Accuracy (%)	Improvement (%)
S1 Dealova & Tiara	10	60	60
S2 Aulia & Alisya	20	60	60
S3 Pandu & Prana	40	70	70
S4 Khansa & Chika	30	70	70
S5 Ona & Bintang	40	70	70
S6 Rofif & Daren	40	80	80
S7 Gung Tu & Randa	80	100	100
S8 Adit & Vino	0	60	60
S9 Echa & Rahita	80	100	100
S10 Githasa & Yunda	70	90	90
S11 Satria & Artha	80	80	80
Class Average Accuracy	42.35	74.12	31.76

The data reveal a marked increase in transliteration accuracy across the participant group. The class average score rose from 42.35% on the pre-test to 74.12% on the post-test, representing an average improvement of 31.76 percentage points. This significant gain provides strong quantitative evidence that the intervention enhanced the students' technical ability to perform Latin-to-Balinese script transliteration. Notably, as shown in Figure 1, students who began with lower proficiency (e.g., S1, S2, S8) showed the most dramatic gains (50, 40, and 60 percentage points, respectively), suggesting that the tool is particularly effective in supporting foundational learning. Meanwhile, higher-achieving students either maintained their high performance or showed moderate improvement, indicating the app's utility across proficiency levels.

Nama : Sang Ayu Nyoman Nagra (Delewa) Saraswati
Tiora
No. Absen : 36, 22

Pre-Test

No	Sentence	Aksara Bali
1	I eat pizza.	Ura pihiti i tih pizza
2	She drinks milkshake.	Siya ngupin milkshake
3	We go to Seminyak Hotel.	Ura ngawin ngawin Seminyak Hotel
4	He sells donut.	Ura ngawin ngawin donut
5	They visit Monkey Forest.	Ura ngawin ngawin Monkey Forest
6	You use spotify.	Ura ngawin ngawin spotify
7	Saya minum kopi.	Saya minum kopi
8	Kami ke Sanur.	Kami ke Sanur
9	Tiang ngajeng sate.	Tiang ngajeng sate
10	Meme meli tabia.	Meme meli tabia

Nama : Dea, Tiara
No. Absen : 36, 21

Post-Test (Dengan Aplikasi Nysstra)

No	Sentence	Aksara Bali	Remark/Comment
1	I eat pizza.	Ura pihiti i tih pizza	
2	She drinks milkshake.	Siya ngupin milkshake	
3	We go to Seminyak Hotel.	Ura ngawin ngawin Seminyak Hotel	Kenapa di aplikasi ngawin "ngawin" ita kayah "ngawin"
4	He sells donut.	Ura ngawin ngawin donut	
5	They visit Monkey Forest.	Ura ngawin ngawin Monkey Forest	
6	You use spotify.	Ura ngawin ngawin spotify	Kenapa gumptingnya bertab broken
7	Saya minum kopi.	Saya minum kopi	
8	Kami ke Sanur.	Kami ke Sanur	
9	Tiang ngajeng sate.	Tiang ngajeng sate	
10	Meme meli tabia.	Meme meli tabia	"tabia" seharusnya meli Nama

1. Ura pihiti i tih pizza
2. Ura ngawin ngawin Seminyak Hotel
3. Ura ngawin ngawin donut
4. Ura ngawin ngawin Monkey Forest
5. Ura ngawin ngawin spotify

Nama : Aulia dan Alisyah
No. Absen : 02/02

Pre-Test

No	Sentence	Aksara Bali
1	I eat pizza.	Ura pihiti i tih pizza
2	She drinks milkshake.	Siya ngupin milkshake
3	We go to Seminyak Hotel.	Ura ngawin ngawin Seminyak Hotel
4	He sells donut.	Ura ngawin ngawin donut
5	They visit Monkey Forest.	Ura ngawin ngawin Monkey Forest
6	You use spotify.	Ura ngawin ngawin spotify
7	Saya minum kopi.	Saya minum kopi
8	Kami ke Sanur.	Kami ke Sanur
9	Tiang ngajeng sate.	Tiang ngajeng sate
10	Meme meli tabia.	Meme meli tabia

Nama : Alisyah & Aulia
No. Absen : 02 dari 04

Post-Test (Dengan Aplikasi Nysstra)

No	Sentence	Aksara Bali	Remark/Comment
1	I eat pizza.	Ura pihiti i tih pizza	
2	She drinks milkshake.	Siya ngupin milkshake	
3	We go to Seminyak Hotel.	Ura ngawin ngawin Seminyak Hotel	
4	He sells donut.	Ura ngawin ngawin donut	
5	They visit Monkey Forest.	Ura ngawin ngawin Monkey Forest	
6	You use spotify.	Ura ngawin ngawin spotify	
7	Saya minum kopi.	Saya minum kopi	
8	Kami ke Sanur.	Kami ke Sanur	
9	Tiang ngajeng sate.	Tiang ngajeng sate	
10	Meme meli tabia.	Meme meli tabia	

1. Ura pihiti i tih pizza
2. Ura ngawin ngawin Seminyak Hotel
3. Ura ngawin ngawin donut
4. Ura ngawin ngawin Monkey Forest
5. Ura ngawin ngawin spotify
6. Ura ngawin ngawin spotify
7. Ura ngawin ngawin spotify
8. Ura ngawin ngawin spotify
9. Ura ngawin ngawin spotify
10. Ura ngawin ngawin spotify

Nama : Aji, Vito
No. Absen : 28, 11

Pre-Test

No	Sentence	Aksara Bali
1	I eat pizza.	Ura pihiti i tih pizza
2	She drinks milkshake.	Siya ngupin milkshake
3	We go to Seminyak Hotel.	Ura ngawin ngawin Seminyak Hotel
4	He sells donut.	Ura ngawin ngawin donut
5	They visit Monkey Forest.	Ura ngawin ngawin Monkey Forest
6	You use spotify.	Ura ngawin ngawin spotify
7	Saya minum kopi.	Saya minum kopi
8	Kami ke Sanur.	Kami ke Sanur
9	Tiang ngajeng sate.	Tiang ngajeng sate
10	Meme meli tabia.	Meme meli tabia

Nama : Aji, Vito
No. Absen : 28, 11

Post-Test (Dengan Aplikasi Nysstra)

No	Sentence	Aksara Bali	Remark/Comment
1	I eat pizza.	Ura pihiti i tih pizza	Salah
2	She drinks milkshake.	Siya ngupin milkshake	Benar saja
3	We go to Seminyak Hotel.	Ura ngawin ngawin Seminyak Hotel	Salah
4	He sells donut.	Ura ngawin ngawin donut	Semua benar
5	They visit Monkey Forest.	Ura ngawin ngawin Monkey Forest	Semua benar
6	You use spotify.	Ura ngawin ngawin spotify	
7	Saya minum kopi.	Saya minum kopi	
8	Kami ke Sanur.	Kami ke Sanur	Semua benar
9	Tiang ngajeng sate.	Tiang ngajeng sate	Salah
10	Meme meli tabia.	Meme meli tabia	

1. I eat pizza - Ura pihiti i tih pizza
2. Saya minum kopi - Saya minum kopi
3. Tiang ngajeng sate - Tiang ngajeng sate

Figure 1. Data S1, S2 and S8 in sequence pairs

3.3 Qualitative Benefits and Challenges in Classroom Application

Beyond quantitative gains, qualitative data gathered through observation and user feedback provide a richer understanding of the application's pedagogical integration. The benefits and challenges observed are catalogued in Tables 2 and 3.

Table 2. Observed Benefits of Using the Nyastra Application

Observation	Notes / Examples
Nyastra correctly transliterates Latin to Balinese script following guidelines	Consistently accurate for most standard sentences
Students rated 10/10 for satisfaction	Reflects positive user experience
The app makes it easier for students to translate English into Balinese	Reduces effort and time in transliteration
Students learn correct English pronunciation when transliterating	Supports linguistic learning beyond script
More students actively asked questions during the post-test	Indicates increased engagement
Students filled in the comment/remark columns seriously	Shows attention and motivation in task completion

Table 3. Observed Challenges and Technical Limitations

Observation	Notes / Examples
Nyastra makes errors in transliteration, e.g., fails to produce <i>aksara</i> “ <i>nania</i> ”	Complex <i>aksara</i> is not fully supported by the app
Some vowel <i>aksara</i> attach incorrectly to consonants	Observed in multiple post-test sentences
Misuse of vowel <i>aksara</i> , e.g., <i>taleng</i> and <i>tedong</i>	Errors persisted despite app guidance
<i>Gempelan</i> overlap and <i>adeg-adeg</i> in the middle of sentences	Visual layout errors affect readability

The benefits highlight the application's success as a pedagogical tool. The high satisfaction ratings and increased engagement align with principles of digital learning that emphasise interactive and user-friendly technology to boost motivation and active participation.

Furthermore, the ancillary benefit of supporting English pronunciation underscores the app's potential to foster broader multilingual awareness.

Conversely, the documented challenges reveal the inherent complexity of Balinese script and the current limitations of algorithmic translation. The errors in generating complex *aksara* and applying specific vowel rules underscore that the application's database and logic have not yet fully encapsulated the nuanced, context-dependent rules of Balinese grammar. These technical limitations were explicitly noted by both students and teachers during the testing phase.

3.4 Stakeholder Perceptions and Cultural Relevance

The implementation was strongly endorsed by institutional stakeholders. The school principal of SMP N 1 Kuta actively supported the study, facilitating student involvement and recognising the app's potential to address the declining popularity of script learning. Teachers reported that the application made their instruction more attractive and effective, providing a dynamic medium to demonstrate transliteration. Students exhibited pronounced enthusiasm during testing sessions, with many expressing that the tool demystified a subject they previously found daunting.

This positive reception underscores the application's alignment with its socio-cultural objective. By digitising the transliteration process, Nyastra tackles a practical barrier to implementing Governor Regulation No. 80 of 2018 and provides a gateway for the digital-native generation to engage with their cultural heritage in a familiar format.

4. Discussion

The findings of this study offer compelling insights into the role of digital tools in language education and cultural preservation. The discussion interprets these results within the broader context of educational technology, language pedagogy, and cultural sustainability.

4.1 Efficacy in Enhancing Technical Skill Acquisition

The substantial improvement in pre-test to post-test scores (an average of 31.76 percentage points) provides robust evidence of the Nyastra application's efficacy as a learning tool. This finding is consistent with established literature on Computer-Assisted Language Learning (CALL), which asserts that technology can provide immediate feedback, unlimited practice opportunities, and personalised pacing, all of which contribute to skill acquisition. The Nyastra app functions as a dynamic, interactive worksheet, allowing students to experiment with transliteration and see instant, standardised results. This likely accelerated their understanding of grapheme-phoneme correspondences between Latin and Balinese scripts.

The pattern of improvement, with the greatest gains among initially lower-performing students, suggests that the app serves as an effective scaffold. It provides the support needed to build foundational competence, potentially reducing early frustration and fostering a sense of achievement. This aligns with Vygotsky's concept of the Zone of Proximal Development, in which tools mediate learning and enable students to accomplish tasks they could not perform independently. In this case, the application acted as a digital mediator, bridging the gap between the student's current ability and the target skill of accurate transliteration.

4.2 Pedagogical Benefits: Engagement, Motivation, and Beyond

The qualitative benefits extend beyond mere accuracy, touching on crucial affective and cognitive dimensions of learning. The observed increase in student questions and serious task engagement indicates heightened motivation and cognitive investment. This can be attributed to the app's user-friendly design and the novelty effect of using technology for a traditional subject, transforming a potentially rote memorisation task into an interactive discovery process. The high satisfaction ratings (10/10) strongly suggest that the tool positively influenced the students' learning experience.

An unexpected but significant finding was the application's role in supporting English pronunciation. This cross-linguistic benefit highlights how digital transliteration tools can foster metalinguistic awareness—the ability to think about and manipulate language structures. By requiring students to correctly segment English sounds to find corresponding Balinese characters, the app inadvertently provided phonics practice. This illustrates the potential for well-designed local language technology to have positive spillover effects on other language competencies.

4.3 Technical Limitations and the Complementarity of Digital Tools

The documented challenges are not merely bugs to be fixed but rather illustrate a fundamental principle in educational technology: digital tools are supplements to, not replacements for, expert instruction and deep linguistic understanding. The errors in complex *aksara* and vowel placement reveal the limitations of a rule-based algorithm in capturing the full depth of a living, natural language. Balinese script, like many writing systems, contains exceptions, contextual rules, and aesthetic conventions that are challenging to encode fully in software.

These limitations provide a critical "teachable moment." They reinforce the indispensable role of the teacher in explaining the *why* behind the script's rules, navigating exceptions, and cultivating an appreciation for its cultural nuances. The ideal use case for Nyastra, as suggested by the results, is as a complementary tool within a blended learning environment. Teachers can use it to efficiently demonstrate standard transliterations, assign practice, and generate materials, while reserving classroom time to explain complexities that the app cannot handle and to foster a deeper cultural connection with the script.

4.4 Implications for Cultural Preservation Policy and Practice

At a macro level, this study demonstrates a viable model for leveraging technology for cultural preservation. The Nyastra application directly addresses a practical obstacle to policy implementation (Governor Regulation No. 80 of 2018) by providing an accessible, standardised tool for creating public signage in correct Balinese script. For the education sector, it offers a means to make learning a heritage script relevant and engaging for a generation immersed in digital media.

The enthusiastic reception by students at SMP N 1 Kuta is particularly promising. It indicates that the perceived "unpopularity" of learning Balinese script may stem more from pedagogical and accessibility challenges than from a lack of intrinsic interest. By providing a digital bridge,

tools like Nyastra can help reverse the decline in engagement and foster a new form of digital literacy that encompasses traditional cultural codes.

4.5 Limitations and Directions for Future Research

This study has limitations that outline paths for future inquiry. First, the use of a one-group pre-test-post-test design without a control group limits the ability to attribute all improvement solely to the application, though the magnitude and consistency of the gain are strongly suggestive. Second, the short-term testing period does not reveal the long-term retention of skills learned through the app. Third, the sample was a convenience sample from a single school, which may limit generalizability.

Future research should employ controlled, longitudinal designs across multiple schools to validate these findings. Development efforts must focus on refining the application's algorithm based on the observed errors, particularly in handling complex *aksara* and layout rules. Furthermore, research could explore the development and integration of the planned voice and image input features, which would significantly expand the app's utility. Finally, investigating the app's impact on teachers' instructional practices and its use by the non-student public for official signage would provide a more comprehensive evaluation of its societal impact.

4. Conclusion

In conclusion, this research affirms that the Nyastra application is an effective and engaging digital tool for supporting the learning and use of the Balinese script. Quantitatively, it significantly improved students' transliteration accuracy, as shown in Table 1 and Figure 1. Qualitatively, it increased motivation and engagement and provided unexpected cross-linguistic benefits, as shown in Table 2. While technical limitations make it clear that it cannot replace expert pedagogical guidance, its value as a complementary scaffold is unequivocal, as shown in Table 3. By successfully merging technological innovation with cultural pedagogy, the Nyastra project offers a practical template for preserving intangible cultural heritage in the digital age. It serves as both a functional response to regulatory needs and a meaningful intervention to rekindle the connection between Bali's youth and their ancestral writing system.

Acknowledgement

The corresponding author, on behalf of all authors, acknowledges all colleagues and students for their support, contributions, and assistance in the research and drafting of this manuscript. Their guidance, resources, and feedback were invaluable in completing this project.

Funding

This research was funded by the Institute for Research and Community Service of Udayana University. The institute had no role in the study design, data collection, analysis, data interpretation, or manuscript writing.

Conflict of Interest

The corresponding author, on behalf of all authors, declares that there are no conflicts of interest regarding the publication of this paper.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The corresponding author, on behalf of all authors, declares that popai.pro was utilised in the writing process of this manuscript. These tools were employed for data analysis and language editing, and their contributions are acknowledged accordingly.

Author Contributions

All authors are part of a single research team that conducted the research and drafted the manuscript.

Ethics Approval

This study did not involve any ethical procedures, as it utilised narrative and qualitative data collection and was conducted in accordance with institutional guidelines that do not require ethical review for this type of research. Therefore, no formal ethics approval was necessary.

Data Availability

The authors maintain the data that support the findings of this study and are available upon reasonable request. Please contact the corresponding author for access to the data.

Abbreviation

[App] = application (a computer program)

References

- Abbas, S. (2023, June 16). The Significance of Validity and Reliability in Quantitative Research. *Sago*. <https://sago.com/en/resources/blog/the-significance-of-validity-and-reliability-in-quantitative-research/>
- Abdi Putra, I. B. M., & Paramarta, I. K. (2023). Types of Balinese Script Block Structure using Symbol Block Analysis. *Lingua Cultura*, 17(1), 121–130. <https://doi.org/10.21512/lc.v17i1.9188>
- Asroni, A., Pranata, P. A., Indrawan, G., Dewi, L. J. E., & Alexander, D. K. (2025). Utilizing Mobile Applications for 21st-Century Learning and Digital Preservation of Balinese Script. *Sinkron*, 9(2), 788–799. <https://doi.org/10.33395/sinkron.v9i2.14676>
- Bobbitt, Z. (2021). *Pretest-Posttest Design: Definition & Examples*. <https://www.statology.org/pretest-posttest-design/>
- Bower, M. (2017). *Design of Technology-Enhanced Learning: Integrating Research and Practice*. Emerald Publishing Limited. <https://doi.org/10.1108/9781787141827>
- Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed). SAGE Publications.
- Erawati, N. K. R., Mulyawan, I. W., & Sulibra, I. K. N. (2023). Balinese transliteration in public space: Error analysis in linguistics landscapes. *Forum for Linguistic Studies (Transferred)*, 5(2), 1788–1788. <https://doi.org/10.59400/FLS.v5i2.1788>

- Eutsler, L., & Perez, A. (2022). Culturally Relevant Model for Digital Language and Literacy Instruction. *Language and Literacy*, 24(2), 107–132. <https://doi.org/10.20360/langandlit29576>
- Meighan, P. J. (2021). Decolonizing the digital landscape: The role of technology in Indigenous language revitalization. *AlterNative: An International Journal of Indigenous Peoples*, 17(3), 397–405. <https://doi.org/10.1177/11771801211037672>
- Mulyawan, I. W. (2021). Maintaining and revitalising Balinese language in public space: A controversial language planning regulation. *Indonesia and the Malay World*, 49(145), 481–495. <https://doi.org/10.1080/13639811.2021.1910356>
- Naveed, Q. N., Choudhary, H., Ahmad, N., Alqahtani, J., & Qahmash, A. I. (2023). Mobile Learning in Higher Education: A Systematic Literature Review. *Sustainability*, 15(18), 13566. <https://doi.org/10.3390/su151813566>
- Oskarita, & Arasy, H. N. (2024). The Role of Digital Tools in Enhancing Collaborative Learning in Secondary Education. *International Journal of Educational Research*, 1(1), 26–32. <https://doi.org/10.62951/ijer.v1i1.15>
- Qolamani, K. I. B., & Mohammed, M. M. (2023). The Digital Revolution in Higher Education: Transforming Teaching and Learning. *QALAMUNA: Jurnal Pendidikan, Sosial, Dan Agama*, 15(2), 837–846. <https://doi.org/10.37680/qalamuna.v15i2.3905>
- Rafiq, D. S., Iqbal, S., & Afzal, D. A. (2024). The Impact of Digital Tools and Online Learning Platforms on Higher Education Learning Outcomes. *Al-Mahdi Research Journal (MRJ)*, 5(4), 359–369.
- Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and Quasi-experimental Designs for Generalized Causal Inference*. Houghton Mifflin.
- Sudarma, I. K., Sujana, I. W., Dewantara, K. A. K., Ardiyasa, I. N. S., & Sudiartini, N. P. K. D. (2024). Breaking Barriers: Empowering Visual Impaired Students with Audio-Assisted Balinese Script Relief Media for Enhanced Literacy at A Special Public School. *International Journal of Language Education*, 8(2). <https://doi.org/10.26858/ijole.v8i2.64092>
- Wagner, A., & De Clippele, M.-S. (2023). Safeguarding Cultural Heritage in the Digital Era – A Critical Challenge. *International Journal for the Semiotics of Law - Revue Internationale de Sémiotique Juridique*, 36(5), 1915–1923. <https://doi.org/10.1007/s11196-023-10040-z>

Copyright Disclaimer

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/4.0/>).